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ABSTRACT

Microgravity-the absence or reduction of some of the effects of gravity-is an important attribute of free-fall. In microgravity (often incorrectly called zero-g), water no longer flows "downhill" and neither do smoke or steam bubbles rise. This changes a number of chemical and physical activities. Experiments in combustion, fluid behavior, materials formation, cell science, and even fundamental physics formed an important part of the research conducted aboard the Space Shuttle in the 1980s and '90s. This educational brief for grades 9-12 provides assembly instructions for constructing a mini drop tower. The drop tower holds demonstration payloads such as a postage scale, a birthday candle, and an oil-drop toy. (MVL)

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National Aeronautics and Space Administration

| Educational Product | |
|---|---|
| Educators & Students | Grades 9-12 |

EB-2003-01-19-MSFC

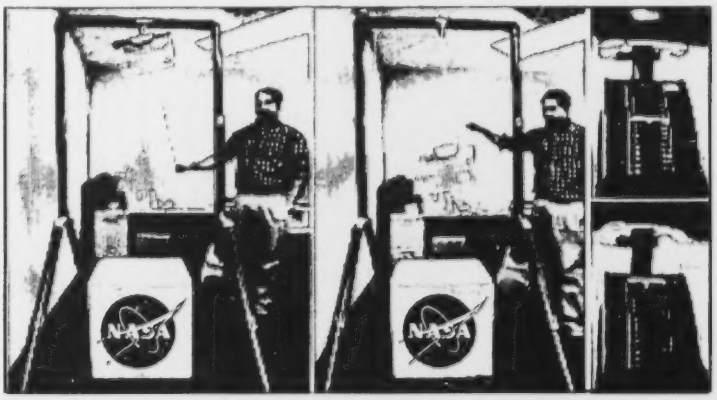
ED 479 516

# Educational Brief

## Wireless Drop Tower for Microgravity Demonstrations

Microgravity — the absence or reduction of some of the effects of gravity — is an important attribute of free-fall. In microgravity (often incorrectly called zero-g) water no longer flows "downhill." Neither do smoke or steam bubbles rise. This changes a number of chemical and physical activities. Experiments in combustion, fluid behavior, materials formation, cell science, and even fundamental physics formed an important part of the research conducted aboard the Space Shuttle in the 1980s and '90s, current studies, and planned for the International Space Station. Studying these changes, and the new products that come from them, give us important insights for improving life on Earth.

A useful tool for communicating microgravity research to students has been the Microgravity Mini-Drop Tower (or Demonstrator) which comprises a support system, TV camera, drop package, TV and VCR. The drop package holds small demonstration payloads — such as a postage scale, birthday candle, or oil-drop toy — that are videotaped for playback after the drop. Students see the scale go to zero, the candle flame reduced in height, and the oil drops stop flowing. This is a scale version of a larger drop tower NASA uses to provide 2.2 seconds of free-fall for complex science research packages.



Familiar, low-cost devices can show the basic effects that occur in a low-g or free-fall environment. This Educational Brief describes how to build an inexpensive drop tower that will let students study the effects of free-fall. The drop tower can be made of PVC tubing (left) or mounted to the top of a step ladder or a second-floor railing. A video system inside the package shows what happens to simple devices, such as a postage scale (left) during free-fall. Video may be captured and replayed on a VCR or on a computer with digital video editing software.

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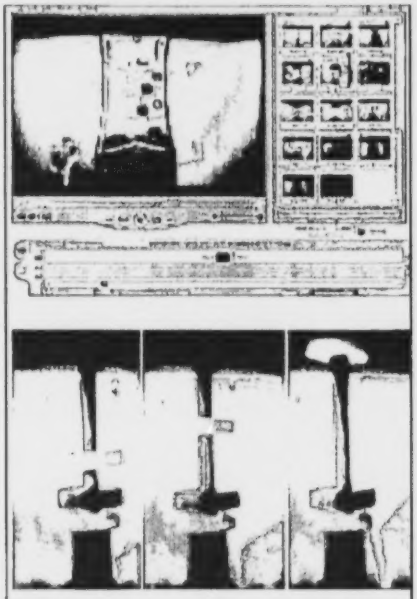
NASA has developed two new versions of the Drop Tower to eliminate the bulk and allow easier use. Each uses a wireless video system to provide a free drop with minimal drag.

The least expensive is version 1, which is a basic kit that uses a TV and VCR to capture the free-fall. Version 2 has a computer, which allows the user to have slow-motion playback. Each is designed with low-cost items for easy replication and will use instructional materials based on the original NASA materials. Key considerations in the design of versions 1 and 2 are student safety, minimal shipping costs, ease of manufacture, and low cost on parts. The new versions and their components are:

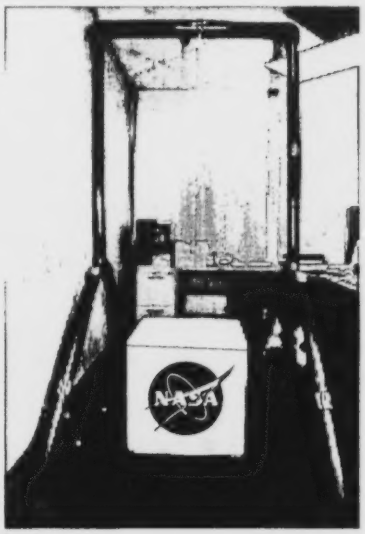
1. A small drop package, video system, a release mechanism, and demonstrator payloads (dripping oil timer, postage scale, etc.). The user provides a drop stand made from PVC pipe, a box filled with foam peanuts (the catch bucket), a TV, and VCR. The video system comprises an X10 wireless camera and receiver system.
2. This version adds a laptop computer with X10 video and VGA ports, and video editing software to capture the video for frame-by-frame playback and analysis. The laptop can also provide PowerPoint presentations for the class and burn a CD copy of the drop experiment video plus whatever NASA materials the teacher wants from the hard drive.



Editing a movie on a computer (top) lets the teacher clip out extraneous activities and save just the drop experiments, such as this sequence showing magnetic repulsion in free-fall (individual frames exported from the movie).

To the maximum extent possible, the new system does not revise the low-g exercises now in the current Drop Tower Demonstration. The intent is to provide a low-cost alternative using components available at local stores or off the Web.

Prototype PVC frame for the drop tower. This version was built with the legs in two segments rather than one, as shown in the drawings.



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## PVC Frame Assembly Instructions

Most supplies can be purchased at home improvement warehouses. Because PVC pipe normally comes in 10-foot lengths, ask a sales associate to cut the PVC into three 30-3/4" pieces and ten 23" pieces (Note: For more accurate cuts, you may cut them yourself). The 2" exhaust clamps are available at an auto parts store.

> ***Caution***: Follow all manufacturer's instructions and safety guidelines with each of the products listed below. All gluing and spray painting should be done in well-ventilated areas to avoid exposure to fumes. Wear workshop goggles during all work to protect your eyes.

**The fine print on trade names and prices**

The use or mention of specific products in this guide does not imply endorsement by NASA. In many cases, alternative products are available and will provide equivalent or similar functions. Trade names are the property of the respective manufacturers and are used as examples. Prices given are typical for items purchased in Huntsville, AL in 2002. Prices will vary with market demands and in different geographic areas.

**Drop tower frame parts list**

| Item(s) | Quan | Unit | Total |
|---|---|---|---|
| PVC tubing (2-inch diameter) | | | |
| 10' PVC stem | 4 | $3.57 | $14.28 |
| in-line coupling | 6 | $0.69 | $4.14 |
| 90 deg. elbow coupling | 6 | $1.28 | $7.68 |
| T-fitting | 2 | $1.97 | $3.94 |
| 45 deg. elbows | 4 | $1.44 | $5.76 |
| PVC glue | 1 | $2.88 | $2.88 |
| PVC glue cleaner | 1 | $2.88 | $2.88 |
| bonding primer | 1 | $2.97 | $2.97 |
| PVC hacksaw | 1 | $5.50 | $5.50 |
| Paint | | | |
| Primer | 2 | $2.37 | $4.74 |
| 1" masking tape | 1 | $0.97 | $0.97 |
| Blue spray paint | 2 | $2.37 | $4.74 |
| Red spray paint | 2 | $2.37 | $4.74 |
| Other | | | |
| Sandpaper package | 1 | $2.29 | $2.29 |
| 2" pipe clamps | 2 | $1.52 | $3.04 |
| 2-1/4" exhaust clamps | 2 | $0.99 | $1.98 |
| 16 oz. plastic bottle | 1 | $0.99 | $0.99 |
| Workshop goggles | 2 | $4.50 | $9.00 |

## PVC Assembly

### Paint Preparation

1. Sand the printed lettering off the stems. Use low to high-grade sandpaper. To make the paint stick, the shiny veneer needs to be dull. You do not have to sand joiner pieces.
2. Peel UPC stickers off of couplings, then sand or remove leftover glue. There are products commercially available for removing glue, but you must clean and let completely dry afterward.
3. Wipe dust off of pieces before priming.
4. Tape ends to at least 1" on stems. This will help disassembly.
5. Prime couplings with bonding primer. You can also spray stems, but since they have been sanded, it's not necessary.
6. Prime stems with primer. Depending on how the stems are organized for painting, you can spray one side, let dry, then rotate. The primer will dry evenly.
7. Lightly use 220-grit sandpaper to remove high spots or dings.
8. Touch-up after the primer has dried. Follow drying time printed on can, but usually a half-hour is enough for additional coats.

### Painting

1. Once primer is dry, again buff with the 220-grit sandpaper, then paint couplings and stems.
2. To reduce sags in paint coats, use intermittent spraying from side-to-side and shake occasionally between sprays. Space parts far enough apart to avoid overspray.



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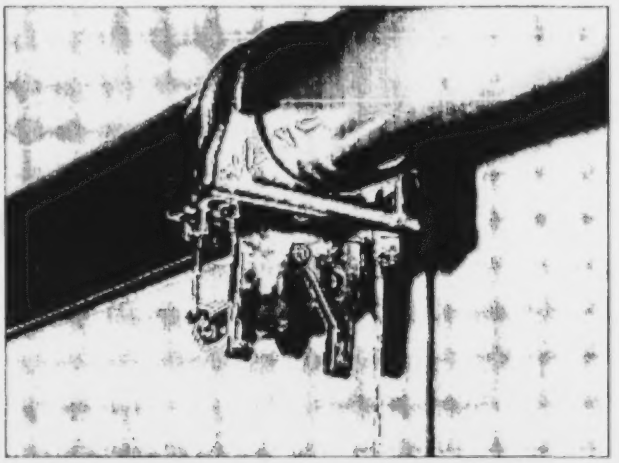
### Pre-assembly

When cleaning and gluing, be sure to hold coupling level. Apply a small amount of cleaner to the inside bead (about a brush-length will do). Do not apply all the way to the edge. The cleaner and glue will eat the paint. Apply a small amount of glue the same way.

1. Gather four 23" pieces and four in-line couplings. Glue an in-line coupling to one end of each.
2. Carefully glue a corner to each end of the 30-3/4" pieces. Be sure they line up in the same direction. It's easier to use a table when adhering.
3. Glue the joiners to the T-fitting so that each are opposite the other. Then, glue the elbows on the joiners so that they are positioned down. Again use a table. There is only a very short time period to correct the position. After 3 seconds, it will be bonded. Glue a 23" piece with an in-line on top of the T-fitting.
4. Repeat this process for the other T-fitting.
5. After all pieces are glued, spray PVC with high-gloss Krylon Clear Coat. This will help protect the paint from chipping.

### Securing the Latch to the Cross Bar

1. Clean and completely remove the label on a 16-ounce plastic bottle. Then cut the ends off to make a cylinder about 2-3/4" long. Snip one side to open the cylinder into a coiled strip. This acts as a scuff guard to protect the bar from the release line.
2. Place the strip around the center of the top piece. Carefully slide the U-bolts over the plastic (on pipe). You may have to pull the bolt stems apart slightly while pushing the U-bolt down.
3. Slide each U-bolt seat onto stems. After that, place the latch base flat against the seats, so that the latch is perpendicular to the pipe. Each base wing or latch plate should rest against its own U-bolt seat, and be between bolt stems.
4. Slide the flat plate onto stems, so it sandwiches the latch base-plate. Then spin the nuts on semi-snug.
5. Place top PVC piece onto stand. Align the latch's position with the uprights (from the side of stand). Tighten a quarter-turn with a 1/2" wrench or pair of pliers.



The hold-and-release mechanism at the top of the drop tower is made from a garden gate latch held in place by two exhaust pipe U-clamps. The latch base plate is sandwiched between the exhaust clamp seat and a 2" mending plate (supplied in the 2" pipe clamp package).

### Assembly

1. Connect all the bottom 30-3/4" pieces to four bare stems, then attach to the elbows at the T-fitting. Connect remaining bare stems to other 30-3/4 piece (note: using petroleum jelly or Talcum powder on ends and inside connectors will also help disassembly).
2. Connect the two pieces with inline fittings to the top of the T-fitted piece. Place top portion of stand onto inline fittings

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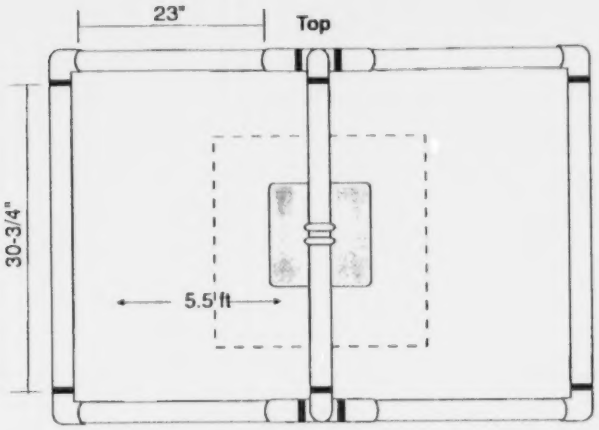
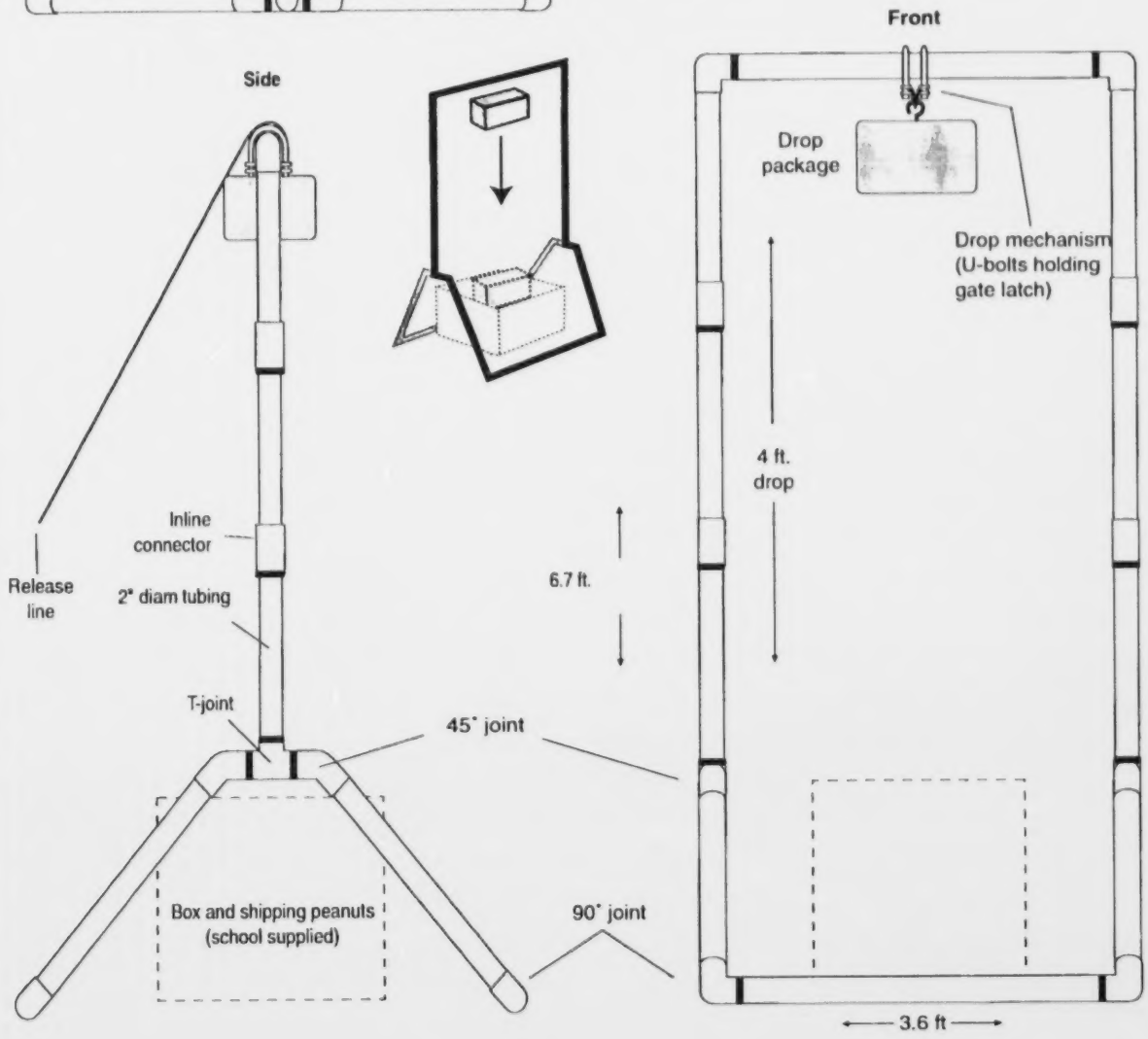
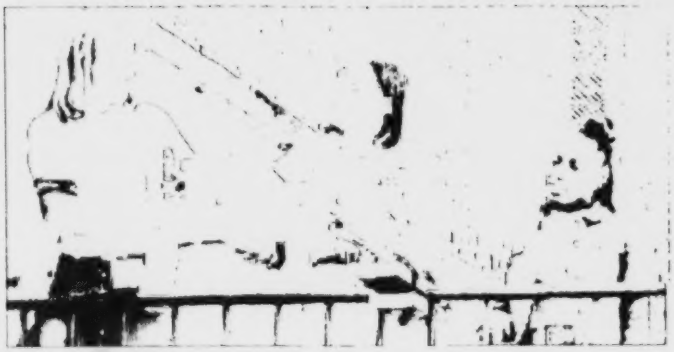


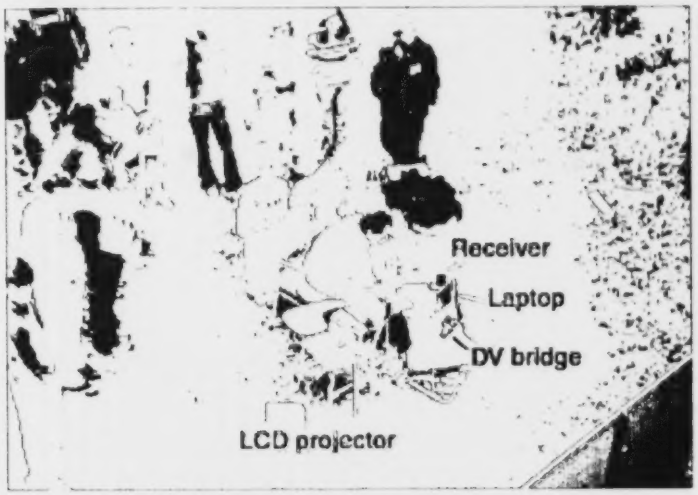

**NASA Classroom Drop-Tower**
PVC tubing assembled by students
Max tube length 3 ft for shipping
Some sections glued (indicated by –) to avoid flexing and part loss
4-ft drop ensures 0.5 second (15 frames of video) of free-fall

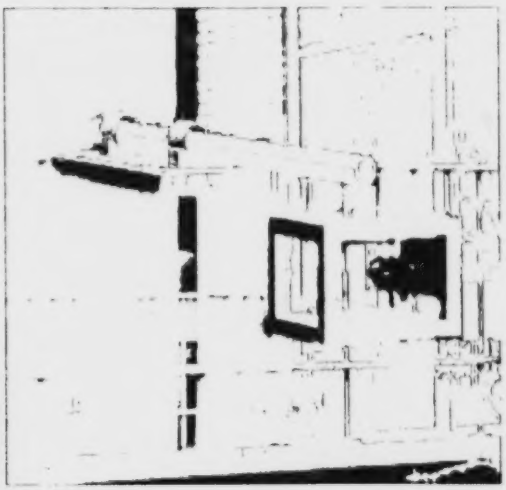
Designed by
Chris McLemore & Dave Dooling
Infinity Technology
Huntsville, AL 35805



The new Wireless Drop Tower gets its first field demonstration at Auburn University. Instead of using a drop tower stand, the drop package was released from an assembly (wood plus a plastic tube; right) mounted to the railing of a pedestrian bridge outside a class building. The target was a box filled with foam peanuts. To increase visibility, an LCD projector was connected to the computer's video-out port and the image put on screen (below). This required setting up in the shade because of outdoor brightness. Note also that this arrangement requires extension cords and multi-outlet power adapters.





**Other Activities**

All of us experience reduced or increased gravitational effects in daily life although we usually don't recognize them as such. Riding up in an elevator we weigh slightly more than normal until it stops; riding down, we weigh less. The same is true on a playground swing at the bottom and top of its arc (at the top you hit near "zero-g" for an instant). These are opportunities for students to use the drop tower systems to measure changes in acceleration. Amusement park rides are another opportunity but should be approached with great caution and preparation because of the potential for the g-forces of a ride to pull the package out of a student's hands and turn the package into a projectile (that's why the ride operators make you take your glasses off). *Do not use live animals in any drop experiments*. An animal's reaction time probably is greater than the drop duration, and impact may disorient, injure, or kill the animal. Responsible animal experimentation involves strict guidelines that are beyond the scope of this document.



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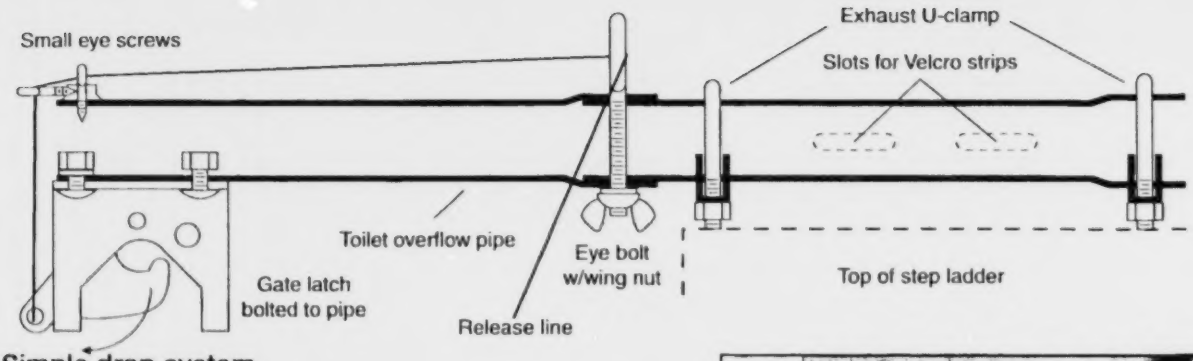
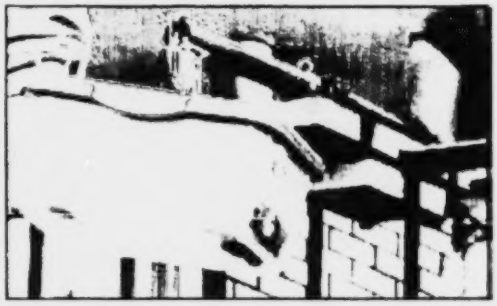



## Simple drop system



The simplest kind of drop tower is a plastic tube to support the drop package atop a step ladder and over a box of foam peanuts. This ensures that each drop is from the same height. It can be adapted to drop the package in stair wells or atriums and thus achieve longer periods of free-fall. However, this also means greater impact velocities and risk of breaking the system, so appropriate safety measures should be taken. This apparatus consists of a gate latch at the end of two lengths of flare-tip PVC pipe held in place by Velcro™ straps and exhaust pipe U-clamps.

1. Insert one pipe into the other and mark the center of connection on the pipe.
2. Drill a 1/4" hole through pipe on the mark.
3. Insert 3" eyebolt through the hole, put on washer and thread on wing nut.
4. At the non-flared end, place latch on the lower side of pipe with release pointing out (latch will be in line with pipe). Mark the boltholes and then carefully drill them.
5. Place latch on pipe. Fasten with bolts and washers (do the inner bolts first).
6. Directly above the latch, make a small hole. Then screw on eye-screw so that it is in line with 3" eyebolt.
7. Tie one end of the string around eyehole of latch release and thread through both eyebolts.
8. On the other portion of the pipe, place exhaust clamps about 8" apart with stems on same side as latch, then tighten snug.
9. Place PVC pipe on top of ladder with bolt stems acting as feet. Loop and thread the two Velcro™ straps around ladder and pipe fairly tight.
10. Place a large box (about 2' x 2' x 20") and one-third full of foam peanuts directly under latch.

Simple drop system parts list

| Item(s) | Quan | Unit | Total |
|---|---|---|---|
| 10/24 x 1/4 nuts and bolts | 1 | $1.44 | $1.44 |
| 1-1/2"OD x 12" flare tip PVC | 2 | $2.37 | $4.74 |
| 3/4" screweyes | 2 | $0.05 | $0.10 |
| 3" eyebolt | 1 | $1.58 | $1.58 |
| 1/4" lock washers | 5 | $0.05 | $0.25 |
| 1/4" wing nut | 1 | $1.55 | $1.55 |
| 1-1/2" exhaust clamps | 2 | $0.99 | $1.98 |
| 34" x 1" Velcro straps | 1 | $4.50 | $4.50 |
| 2" gate latch | 2 | $2.97 | $5.94 |
| 4' piece of string | 1 | $1.00 | $1.00 |
| 6' ladder | 1 | * | |
| cardboard box ~2' x 2' x 20" | 1 | * | |
| bag of foam peanuts | 1 | $4.00 | $4.00 |
| Total (excluding tax) | | | $27.08 |

*Provided by user



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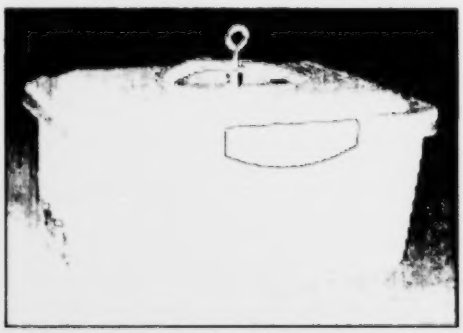
## Building the Drop Package

Drop package parts list

| Item(s) | Quan | Unit | Total |
|---|---|---|---|
| Plastic container ~6 x 9 x 14" | 1 | $2.96 | $2.96 |
| 1/8" x 1" bolts | 2 | $0.31 | $0.62 |
| 1/8" wide washers | 2 | $1.11 | $2.22 |
| 1/8" x 3/4" wood screws | 2 | $0.22 | $0.44 |
| 1/4" x 3" eyebolt | 1 | $1.58 | $1.58 |
| 1/4" fender washers | 2 | $0.21 | $0.42 |
| 1/4" wing nut | 1 | $0.30 | $0.30 |
| 5/16" nut or slightly larger | 3 | $0.17 | $0.51 |
| adhesive-backed Velcro™ | 1 | $2.49 | $2.49 |
| strip of loop-type Velcro™ | 1 | $1.49 | $1.49 |
| 2" x 24" balsa wood strip | 1 | $1.99 | $1.99 |
| soldering iron or wood burner | 1 | $7.99 | $7.99 |
| Craft knife | 1 | $1.00 | $1.00 |
| Total (excluding tax) | | | $24.01 |

1. Drill a 1/4" hole in the center of the box and plastic handle.
2. Spin a nut all the way to the top on eyebolt with a washer beneath it.
3. Insert the bolt through the handle. Between handle and top spin a nut on leaving about a 1/2" of bolt free. Stick the rest of the bolt through the lid. If too tight, pull up on handle (it's adjustable). Put a wide washer and tighten a 1/4" wing nut on it.
4. Place the camera and battery pack on one side to ensure they will fit. Place the battery pack upside down, so you can replace the batteries without removing the pack, and rotate to where the on/off switch is accessible (the battery pack should be in the corner to allow enough room for the camera).
5. With the antenna positioned up, slide the camera with its back to the wall to make sure it will fit without the antennae poking out of the top of container. Then remove.
6. Hold the pack against the bottom (upside down), and turn the box over to mark the mounting holes on the flip side of battery pack. Use a marker to dot the holes. Remove the battery pack and carefully drill the holes with a 1/8" bit. Shave off plastic debris with a craft knife.
7. Coil the excess wire into the bottom of battery pack, leaving 2" of connector wire out. Loop wire with a bread tie. Insert the incoming excess strand into the narrow split in the plastic, then slide the outgoing wire in the space provided. Turn the battery pack over with wire coil inside, and place in position.
8. Use the small 1/8" x 3/4" screws with washers to fasten the battery pack to the box. Do not overtighten.
9. Put the camera next to the battery pack with its back against the wall. Move the bottom wire to the side so the camera will sit down. As with the battery pack, mark the mounting holes on the plastic container.
10. Drill the 1/8" holes, and remove excess plastic. Connect the camera wire to battery pack connector before mounting. Insert the mounting bolts so the bolt stems come out the back (1/8" x 1").
11. Holding the camera and bolt heads, slide the bolts through the plastic. Place mounting plate onto stems, then tighten nuts to snug. Do not overtighten.





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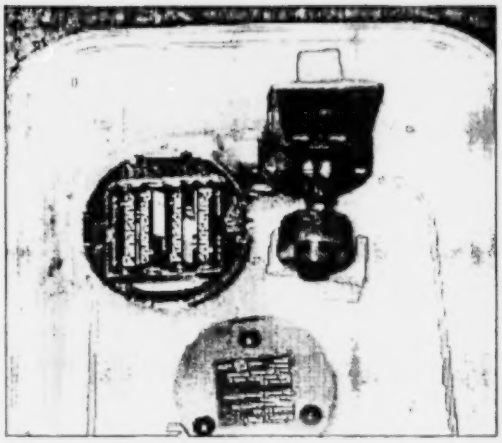
### Securing Camera



1. Stick a half-inch square of hook-type Velcro™ to the back of the camera's antenna and also to the plastic wall opposite it. Make a 3/8" thick spacer out of balsa wood, and stick a tab of loop-type Velcro™ on each side. Put a spacer between the antenna and wall.
2. Point camera toward payload. Hook up video to be sure it's positioned correctly. Measure distance between bottom of camera-eye and floor of container (about 7/8").
3. Glue a spacer together out of 1/8" thick balsa wood, 1- 1/2" long, 3/4" wide and the height of above distance.
4. Place beneath camera (chin rest). Then remove. Glue smaller pieces on each side of chin rest to cradle the lower part of camera eye. Three steps on each side are enough. Glue panels front and back of the chin rest. The back panel will need to be notched around the arm.
5. Power up video system and check operation. Focus camera by rotating lens outward. Because the object to be observed is so close to the camera, it will seem that you are almost removing the lens from the camera.

### Making Way for Payloads

1. Cut a 2" square out of hook-type Velcro™. Center on the bottom of the box opposite of the camera.
2. Place cylindrical oil flow toy flat on top of Velcro™ and against side. Mark two lines on the outside of box (behind timer), in line with the outer edges of the timer, or about 1-1/2" apart.
3. Remove timer. To ensure clean cuts without cracking, use a wood burning or soldering iron to melt two rectangular slits in the container about 1/4" wide and 5/8" high. If it does crack, drill a 1/8" hole just below end of crack. Secure with a short bolt, washer, and nut.
4. Use a craft knife to square up the holes and clean away melted plastic. Again with knife, cut into the inside lip of the lid on the payload side (the side of lid that will be directly above payload side). In the center of the inside lip, cut 1/4" down, and 2-3/8" wide piece out of it. The perpendicular reinforcement will also need to be reduced about 1/4".
5. Between the above cut and centered with the end of the handle (underside of lid), glue a 1-1/2" square wood spacer. Cover the spacer with a piece of hook-type Velcro™.
6. Place loop-type Velcro™ on all the tops and bottoms of payload demonstrations (the scale will need a spacer glued to it).
7. Make a Velcro headband for the cylindrical timer. Use a strip of loop-type Velcro™ (8-1/4" long), glue a 3/4" tab of hook-type Velcro™ to the flip side on one end. This will wrap around the upper part of timer and fasten through the slots.

A miscible fluid payload.

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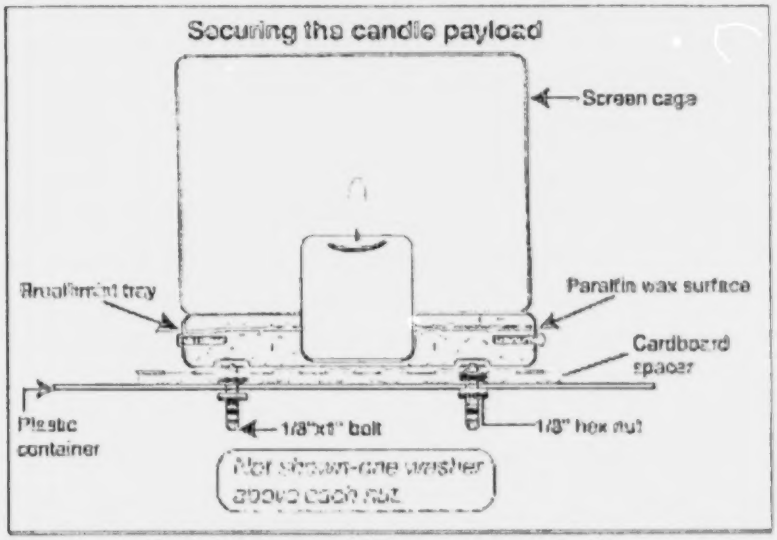
8. The magnet stand and flat, narrow timer are held in place by the top and bottom of the plastic box.
9. Place firebox so it straddles bottom Velcro™ pad and is about 1-1/2" away from the box's back wall. Mark and drill where the bolt stems touch (see below).




For added steadiness during free-fall, glue two strips of corrugated cardboard flat on the underside of tray, on each side of bolt stems (front and back-See picture on pg.14). will reduce the tendency for the firebox to rock back and forth.

**Measure twice, cut once**

1. Draw a measured schematic of structure outline on paper (see diagram 1, and steps 5 and 6).
2. Start with the top of the box 3-5/8" x 2-1/4". If necessary use the lid of the breath mint tin.
3. Cut a yard of aluminum screen.
4. Lay paper schematic beneath screen and sketch the outline (be sure to draw all lines of each shape).
5. From the top edge of the center rectangle draw two consecutive squares that are 3-5/8" in size. Now fold the screen in two so that you can still see the marked outlines and the schematic is completely covered.
6. The entire schematic shape is similar to an upside down "T", however to make cutting easier, mark out a rectangle with the measurements 18-1/8" long and 9-1/2" deep. The void areas on either side of the needed portion is 7-1/4" x 7-1/4".

**Candle payload part list**

| Item(s) | Quan | Unit | Total |
|---|---|---|---|
| large handle scissors or tin snips | 1 | $6.99 | $6.99 |
| roll of aluminum screening | 1 | $5.99 | $5.99 |
| black permanent marker | 1 | $1.59 | 1.59 |
| ruleror measuring tape | 1 | $6.99 | $6.99 |
| paralfin wax | 1pckg | $1.99 | $1.99 |
| wood screws (1/8" x 7/8") | 1 pckg | $0.87 | $0.87 |
| bolts (1/8" x 1") | 1 pckg | $0.87 | $0.87 |
| washers (1/8" ID) | 1 pckg | $0.87 | $0.87 |
| nuts (1/8" tapped) | 1 pckg | $0.87 | $0.87 |
| breathmint container | 1 | 1.99 | $1.99 |
| food warmer candle | 1 | 0.99 | $0.99 |
| heavy duty picture hanging wire | 1pckg | $2.99 | $2.99 |
| needle-nosed pliers | 1 | $5.99 | $5.99 |
| hammer | 1 | $6.99 | $6.99 |
| roofing tack, or small nail | 1 | $0.21 | $0.21 |
| wood block (2" x 1-1/2" x 1-1/2") | 1* | N/A | N/A |
| Total | | | $46.19 |

*any material to use for support



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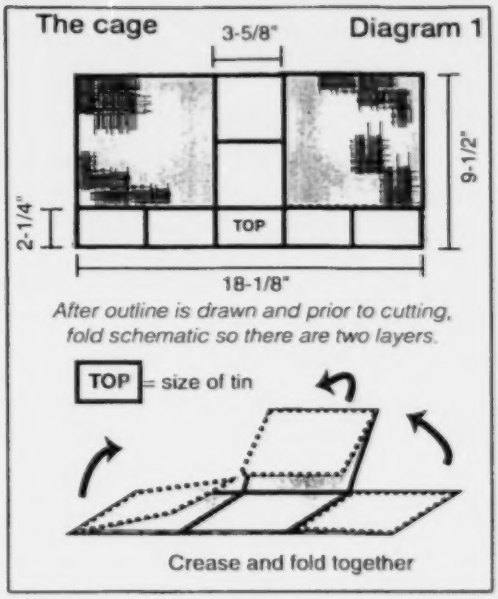
7. Cut out the "T" shape, but do not throw away void squares. Keep the second layer connected to the first. That is, do not separate into two schematics. Then fold each of the three arms over once to align with the adjacent rectangle (see Diagram 1)




### Sewing with metal

1. Fold the top edges so the adjacent sides (back and two sides) are close to each other's edge.
2. Peel off single strands of aluminum from the void squares, and place them in an easily accesible area.
3. Move two edges together to form a corner. Then thread the aluminum strand through both sides at the corner about a strand or so from the severed edge. It's good to start about half way along the length or height of the corner.
4. Tie the strand tight in a simple knot. This will hold while the edges together while adding more strands. The goal is to hold the edges together, but reduce the number of frayed ends. Now, use several strands to stitch the seam together. Either by tying a knot with the two ends around the corner seam and using the remaining ends to tie another suture near the first (an 1/8" –1/4" apart). Another way is to stick just enough wire through to tie a knot and use the remaining long end as thread and sew the seam together. (*This can be monotonous and may get frustrating-take breaks often. Preserve your patience, the strand tip will bend and break sometimes, but keep at it.) Stitch the other corner seam as described above.

### Securing the hood

1. Place the screen hood into the breathmint tray. The bottom corners of the open face edge will have to be bent inward slightly to insert. Push hood down until its bottom edge is completely touching the floor of the tray.
2. Measure and mark the screen where the top lip of the tray meets it on both sides next to the opening. Cut a 1/2 " incision in the screen level with the top of the tray's lip on the left and right sides, and then fold these tabs back, so that they are on the inside of the screen hood. Now the hood should fit snugly inside the tray. On the tray, mark two spots on the outside of the edges (see reference chart) about a 1/2" from the front side (same place where the folded tabs are, but on the opposite side of tin. The dots should be in the location so that when you put a screw through them, the screw will penetrate each tab.
3. Use a small block of wood for support against the dotted side on the inside of the tray and lightly hammer a roofing tack to make a hole on the dot. If tray edge bends, try to pull it back as straight as possible. Now, drive the wood screws (1/8" x 7/8") through, making sure they catch the screen tabs.
4. On the back of the tray, be sure hood is seated firmly on the tray and use the nail to make holes in the screen through the lid slots. Bend the tabs on the slots back a little. Then, use the

picture hanging wire to thread through the holes, so that both ends of wire come out the back of tray. Twist the ends together with your fingers until snug. Use a pair of needle-nosed pliers and twist two times around or until wire is taut. Clip excess wire, but leave enough so you can hide the excess with one of the tabs.

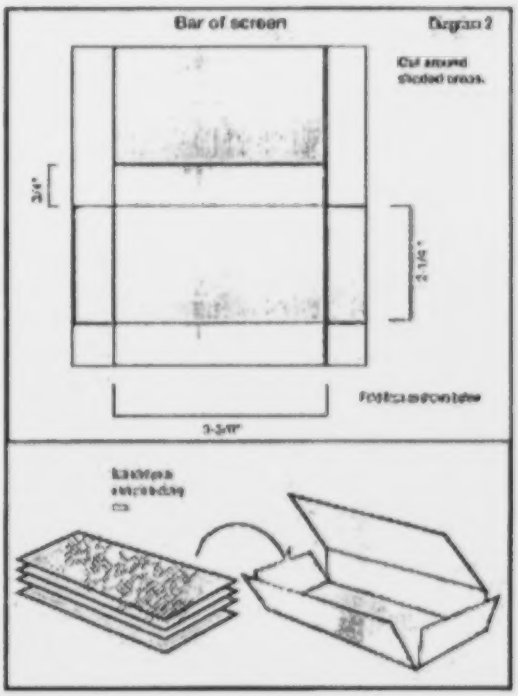
5. Make a hole on the bottom of the tray on each side using the ends of the screws as a guide. Put the holes below the tip of the screw or just in front of it.These two holes will be where you will attach the firebox to the drop package. Use the nail and wood again. It may be easier to push through the tray from the inside down, so put wood underneath tray to protect your work-table. (The bolts will be added later.)

> The hood has four layers of screen on each side except for the top, which has two. For additional fire safety, the heat sink (hood) needs to have at least six layers on each side.

### Adding more metal

1. Repeat the steps described in the beginning to make an additional layer, however do not fold "T" after it is outlined. This will add the 2 needed layers on all sides.

### Making a bar of screen




1. Cut out a rectangle of screen (5-1/8" x 6"). Turn sheet so short edge is facing you. Using the marker, mark 3/4" in, from each left and right side. Mark the same spot on opposite side, then connect the marks so there are two vertical lines. Using these lines as endpoints, make a rectangle 3-5/8" long (along the bottom edge) and 3/4" deep. Then make a rectangle 2-1/4" deep on top of previous, but extend horizontal lines past endpoints to end of screen. Make another 3/4" deep rectangle. Now, you should have a total of six rectangles (see diagram 2).
2. Using the diagram cut out the void area. This is will be the box that will cover the top of the firebox. Go ahead and bend flaps up and make the box without connecting the flaps. Ensure that it doesn't overlap the firebox top more than 1/8" (Ideally it shouldn't overlap).
3. Using the void squares from before, double and cut them to the size of 2" x 3-3/8" or cut out about a dozen of this size (this is the filler for the box described above). Stack screen pieces inside the box cover. That is, in the part with the 3/4" flaps bent up in a cradling position (see Diagram 2). Continue to stack pieces in until filled. Then close the box and seal the corner seams as described in **Sewing with metal**, step 4.



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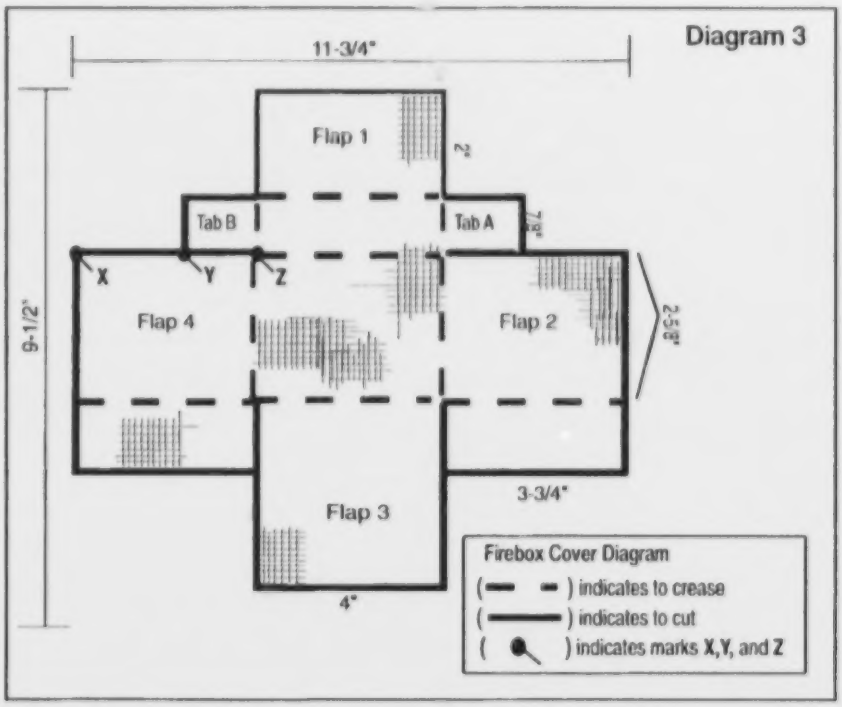
4. Place the bar of screen on top of the firebox, and secure it to the top on four sides (front, back, left and right). There is no need for a lot of tie-downs; two per side is fine.

### Final draw

1. Cut out a rectangular piece of screen that is 11-3/4" x 9-1/2". Orient the rectangle with the longer side facing you ( see Diagram 3).
2. At the bottom edge make a center mark at 5-7/8". Then mark 2" off in each direction from the center mark. From the bottom edge draw a 4" line through the 2" marks (the lines should be perpendicular to the bottom edge. Move down 1-1/4" from the top of each recently drawn lines, and put a visible dash here.
3. Continue this dash to the end of the screen horizontally i.e. for the right line, continue the line to the right, for the left go left. From the end of this line make a visible mark 4" up (Mark X).
4. Now, take a ruler to the original 4" line so the ruler continues to the top of the piece of screen. Draw 2" lines from the top of the screen down in line with the bottom 4" lines. At the end of the 2" line draw a 1-1/2" horizontal line (to the left for the left line and to the right for the right line-). At the end of the 1-1/2" line, draw a 7/8" line down (at this endpoint-Mark Y). Put the ruler at the top to measure each 2" line. Put a mark at the 4" mark (two inches past where the 2" line ends-Mark Z).
5. Use the ruler to draw a horizontal line beginning from the side of the screen sheet and connecting Marks X, Y, and Z (see Diagram 3). The final outline should look somewhat like a cross.
6. This will cover the firebox and shield any fraying wire left over from previous sutures.
7. Cut along the outside of outline, but also cut a 1-1/2" incision between marks B and C on each sides, and snip the entire 4" on the bottom sides (continue 1-1/4" past the dash as described in #2.
8. Place cover face down as it was before cutting. Jot down the following labels to aid in attaching cover: the top portion (2" flap minus wings) is Flap 1, continuing clock wise, the adjacent 1-1/2" x 7/8" flap is Tab A, the right flap is Flap 2, the bottom is Flap 3, the left is Flap 4, and the other small flap is Tab B. Due to the flexibility of the aluminum, some additional trimming may be needed.

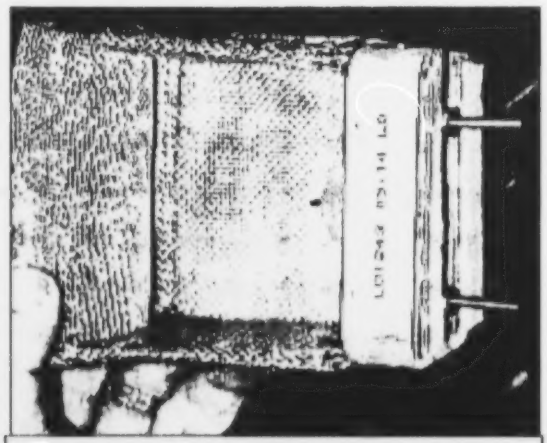


### Covering it all

1. Fold flaps 1-4 and Tabs A and B 90 degrees in the same direction. That is, make a basket shape. Loosely set cover over firebox, and then take small squares of screen about 2-1/2" x 2-1/2" and wrap both edges of the opening (see construction sequence).
2. Fold Tabs A and B underneath Flaps 2 and 4 and fold Flap 1 inside so that it is flat against the ceiling of the firebox.
3. Lift Flap 3 and fold excess of Flaps 2 and 4 against the back of the firebox (under Flap 3). Fold Flap 3 on top. Begin stitching seams on all corners. Flap 1 will also need to be secured. To do this, sew around the perimeter of Flap 1 by pulling the flap back, inserting "thread" from outside of box to inside just beneath ceiling and pull through the edge of the flap close to where the "thread" enters the inside. Two to three ties per side should do the trick for Flap 1. The rest of the seams will need complete sutures, especially the gaps where Tabs A and B meet Flaps 2 and 3.

### Bring on the wax

1. Insert 1/8" bolts through bottom of tray and spin the washers and nuts to seal this connection.
2. Lay old newspaper on countertop a safe distance from stove. Place firebox on block of wood so it is level.
3. Boil a pot of water, and use a small aluminum can with the top cut off or a soup can for the next step.
4. Place a broken stick of paraffin wax inside can. Using tongs, hold and place can in boiling water until wax completely melts.
5. Lift can out of boiling water. Move pot to different eye on stove. Use pot holders to pour about an ounce of wax through a funnel (a cutout top of a plastic drink bottle works well) into breathmint tray.
6. Place and center a food warmer candle into the tray. Pour more wax into tray so it covers the inside screws. (Note: Some wax may leak from 1/8" bolts---this is OK).
7. Allow a couple of hours to cool and dry. If wax doesn't cover screws, repeat instructions 2-4.



Glue one strip of cardboard along each side (front and back) underneath the candle payload to prevent excessive wobbling.



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## Construction Sequence

(The additional layer of screen described after securing the hood is not shown below)

Figure 1

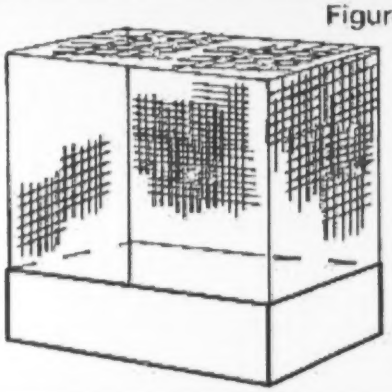


Figure 2

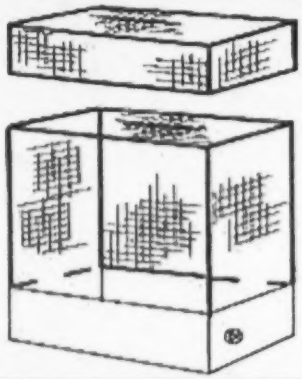


Figure 3

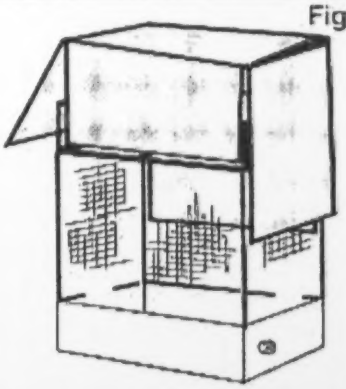


Figure 4

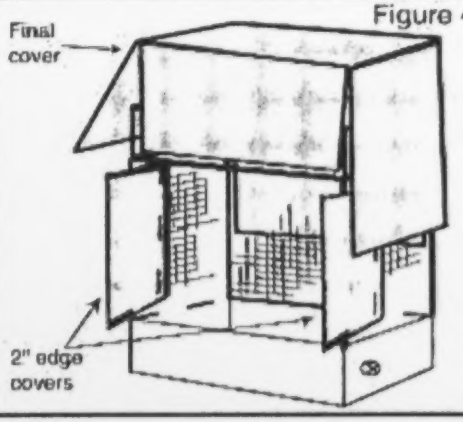



Figure 5

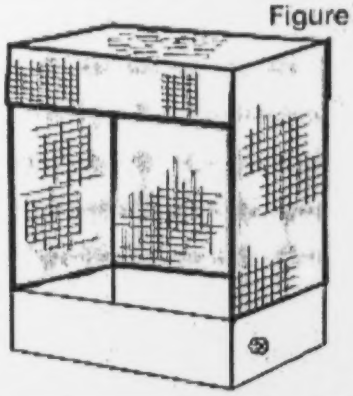
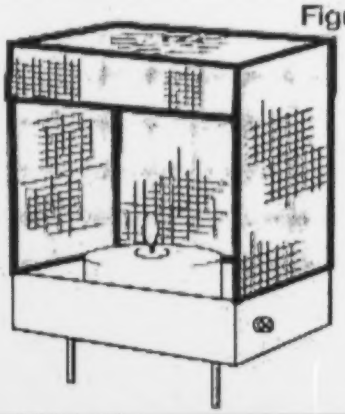


Figure 6



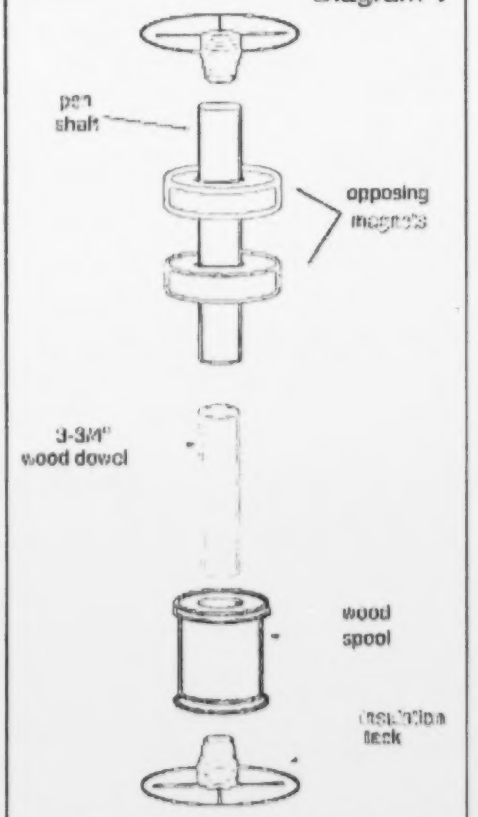
**Remember to ensure all sides and corner seams are free from prickly pieces of screen that might cause harm to handlers.**

## Making the Magnet Stand

| Magnet stand part list | | | |
|---|---|---|---|
| Item(s) | Quan | Unit | Total |
| 1/4" OD x 3-3/4" wood dowel | 1 | $1.99 | $1.99 |
| disposable pen | 1 | $1.29 | $1.29 |
| auto hood insulation tacks | 1 | $1.59 | $1.59 |
| magnetic rings | 1 set of 12 | $3.95 | $3.95 |
| wood glue | 1 | $1.99 | $1.99 |
| sandpaper (80 and 150 grit) | 1 pckg | $1.49 | $1.49 |
| wood spool (1-3/16" x 7/8") | 1 pckg | $2.99 | $2.99 |
| hacksaw or craft knife* | 1 | $0.99 | $0.99 |
| Total | | | |

1. Remove lettering along pen shaft using low to high grit sand paper (surface should be free of printed letters and smooth. Use a hacksaw and cut shaft so it is 4-3/8" in length.
2. Insert an insulation tack into one side of wood spool. Glue a small strip of paper about 1/4" x 1" around the end of wood dowel Put dab of glue on the end and rub it around the circumference of dowel end, then take 1/4" edge of paper and wrap around dowel. This will act as a spacer.
3. Put a couple of drops of glue on and into the hole opposite the tack. Insert dowel in to spool (where glue is) and ensure straightness. Wipe off excess glue and allow it to dry.
4. After dowel sets, smear a small amount of glue along wood dowel. Slide plastic pen shaft over wood and clean up excess glue. (Be sure to clean glue off outside of pen shaft if present on shaft).
5. Slide opposing magnets on to pen shaft. Cap pen shaft with other insulation tack.
6. Cut 1" squares of loop-type Velcro™ and place at each end of stand (on flat side of tack). Total height should be 5-3/4".

Diagram 4




## Securing each experiment

**Cylindrical timer**-place on pad with Velcro™ strip strapped around the upper part like a headband. Position the strip with flat side against timer surface threaded through slots of plastic. Then fold hook-side over onto looped.
**Narrow modular timer**-place bottom on pad and be sure top fastens to hook-side when putting the container lid on. There is a square pad on the underside of lid.
*For the liquid timers, prior to latching and recording turn container upside down to drain colored-oil to top.*
**Candle payload-** Assure bolts are tight extending from underside container. If not hold stem tip with pliers and rotate nuts snug. Slide stems through bottom of plastic box, and fasten with washer and nuts below container.
**Postage scale**- Place scale down on pad with the back against wall of the container. Put the weight down on scale so each Velcro™ pad matches up.
**Magnet stand**-Attach same way as the flat modular timer.



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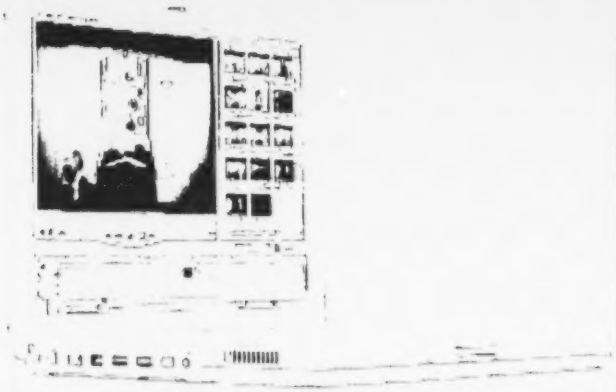
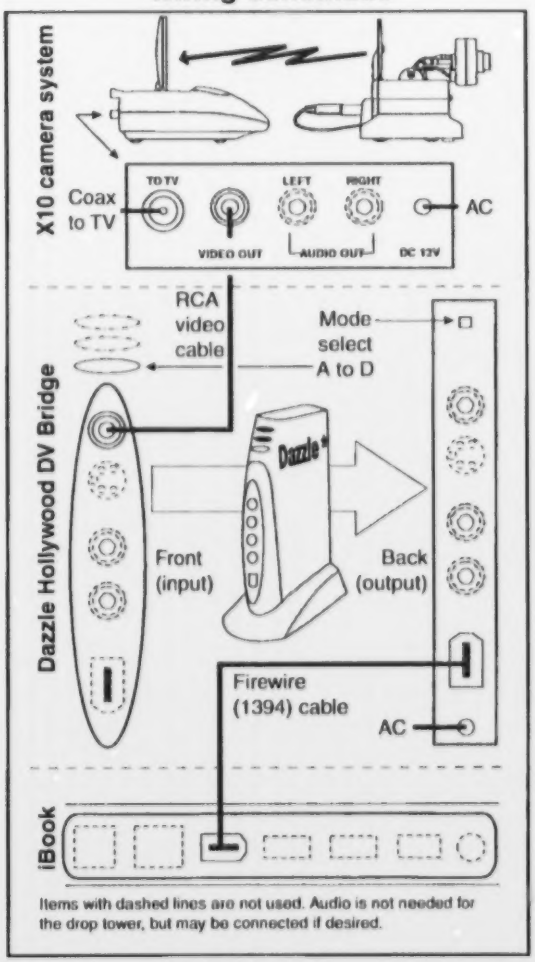
# Video System Design



## Wiring Schematic




Items with dashed lines are not used. Audio is not needed for the drop tower, but may be connected if desired.

**Drop tower video system parts list**

| Item(s) | Quan | Unit | Total |
|---|---|---|---|
| Basic system | | | |
| X10 wireless camera/receiver | 1 | $89.00 | $89.00 |
| X10 camera battery pack | 1 | $20.00 | $20.00 |
| VCR * | 1 | 0 | 0.00 |
| TV * | 1 | 0 | 0.00 |
| Subtotal | | | $109.00 |
| | | | |
| Digital recording | | | |
| Apple iBook or iMac # | 1 | $1,200.00 | $1,200.00 |
| Dazzle Hollywood DV Bridge | 1 | $260.00 | $260.00 |
| | | | |
| Total | | | $1,569.00 |

* Provided by user

# Any Mac with a Firewire port and iMovie; price will vary with configuration.

Note: Electronics prices are highly volatile.

### Alternative Video Concepts

Students and educators should not feel constrained to follow the hardware choices made in this prototype. Options include:

- Use a camera with a hardwire connection to a computer with video software. Webcams are quite affordable, but most use USB connections that are slow at full frame size (a few blurry frames on a drop) or have reduced image size at normal frame rates (320x240 rather than 640x480 pixels). The cable may restrict the distance the package can drop. Do not run the cable over the support structure as this will cause drag. Make sure you pick a camera that works with the video software. A webcam with a Firewire connection should allow real-time, full-frame imagery.
- Mount a digital video camera in the drop package. It can be connected to the computer for the drops, or left disconnected until playback after the drops. Digital cameras provide sharper images. However, there is some risk of damaging the camera's tape drive through repeated impacts, so use lots of foam packing peanuts to absorb the impact.
- Many digital still cameras have movie modes in which they will take a series of still frames until the memory chip is full. Explore this as an alternative for getting high resolution frames of fluid flow in low-g. Timing the camera release and package release so the camera does not quit before the drop starts may be a challenge.

Or, have students run their own design project, thus requiring them to research available technologies and live within resource and safety limits, just as NASA-sponsored scientists do.



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## Hooking things up

1. Unfold signal receiver and plug in AC adapter where marked 12VDC. For computer-less kits, plug RCA cord into video in on TV or VCR. For computer-included kits proceed to step 2.
2. Then place the Dazzle ™ digital / video bridge into the stand (the gray input side slides into side with teardrop-shaped hole on stand). Plug the AC adapter marked Dazzle into the AC jack on the Dazzle bridge (the lowest slot on back of bridge).
3. Plug the yellow RCA cord into the yellow jack on back of receiver and plug the other end into the yellow jack on input side of bridge (top input slot).
4. Plug the black cord marked 1394 (fire wire) into the fitting just above the AC cord on back of bridge (rectangular-polygon shape). The other end plugs into the corresponding slot on the laptop computer, third from the end on left and the same shape as on the bridge.
5. Plug the dark gray plug into the back right side of laptop. This is the AC adapter cord for the computer.
6. Plug the video adapter into left side of the laptop into the outlet that has a rectangle within a pair of parenthesis illustrated (it's the port one-back from the headphone connection). Connect RCA wire from video adapter to video-in port on TV or other media projector.
7. To accommodate for all the AC adapters use a powerstrip with more than 4 outlets.

**How it works** : The camera sends the image to the receiver, which sends the analog signal to the bridge. The bridge converts the signal to digital, and sends the digital data to the computer, where it is translated into a video image.

## Preparing to drop

1. Insert the batteries accordingly into the camera battery pack. Turn switch to on.
2. Turn on laptop. Click on aliases tab at bottom of screen or move cursor to the bottom and a alias display will appear. Open Imovie video editing software. A window will open with a blank storage bank on the right and a control panel with blue video screen on the left. To the left of the control panel will be a filming and editing switch. This toggles the controls from filming (a camera icon) and editing recorded clips (a filmstrip icon). The camera icon is used when the camera is either filming or recording. The filmstrip icon will be used to erase unwanted portions of a file or add other effects to a clip. (For example, after a drop has been recorded, the before and after segments of the drop can be deleted to show only the free-fall action. This will not only reduce the number of frames, but will also reduce the amount of file memory.)
3. Assure the camera is focused and positioned correctly by moving the toggle switch to the camera setting and pressing the play button on the control panel. **Note:** The blue screen will have "camera connected" when it's not playing. If it doesn't, check all wire connections.
4. Once the image appears, place an experiment subject onto pad and focus the image by rotating the outer lens of the camera. Be careful not to touch the lens.

## Recording

***Remember to check the camera's position and focus prior to recording.***

1. To record a drop, place experiment package onto Velcro™ pad and secure the lid by snapping side clamps. Connect eyebolt on top of container to the latch. Then center catch box below. It's good to do a practice drop to assure a clean landing.
2. Move switch to camera icon. Then click import to start recording. This imports the video to file, similar to importing clips to file. The import button starts and stops recording. Pull the release.
3. After the package lands in box, click import to stop recording. To review video, hit play button. As with the import button, the play button represented as the large triangle pointing right will start and stop the playback. Clicking the mouse at different spots along the location bar will move the indicator to that spot. For fine-tune searching or viewing, the right and left arrow keys will move the movie along forward and backward (frame by frame). By pressing the play button, the video will show the entirety of what has been recorded.
4. Cutting the "dead time" out of the file makes for easier viewing. This means removing the footage of the package being latched, resting prior to release and after it has fallen. Having only one or two frames of these states is the most effective.

## Editing

1. Before editing clip, drag the clip icon (looks like a 35mm slide) from the storage bank at the right and drop it into the bar below the control panel (it has a picture of an eye and a clock face to the left of it). Click on the clock face and the clip should appear as an orange linear strip. This is the table that can connect clips into one consistent movie. Like a doctor's table for movie clips, this film track keeps up with the length of individual clips and attributed effects. Think of the storage bank above right as a shelf to store saved clips. They are saved, but they are not apart of the movie.
2. In the display window, a still image of the beginning will appear. Beneath the screen will be a clip meter and a position indicator (an inverted triangle). This identifies the number of seconds and frames the film is displaying at any given moment.
3. Using either the mouse or the arrow keys search the location bar for the frame that depicts the subject a few seconds before it falls. Then back up maybe two frames. This is one cut mark. Place the mouse pointer just beneath the location bar on the grid and click and hold. Two triangles will appear back to back like bookends. These are the cropping tools. The dead time can be removed by using the bookends. By using the mouse, find the cut mark prior to dropping and make the bookends appear. Drag the left bookend back to the beginning of the clip. This should time segment should appear as an orange strip—then hit delete. Repeat this process for after the drop, yet use the right bookend and move it to the end of the file.
4. Editing cuts out the dead time and ensures top software performance as well. If I-Movie automatically shuts off or locks up with miscellaneous text appearing on the screen, open I-movie again or reboot the computer. The computer is letting you know it has too much

used memory to process the task. To fix this problem, get rid of unnecessary files by throwing them away, and emptying the trash bin. A few short files may be kept on the shelf and sustain optimum operation. To keep larger files as a resource burn them to a disc and then toss them to maintain peak performance. Most CD burners will allow you to drag and drop files to be copied.

### Hitting the brakes on free fall

The recorded clip's play speed can be adjusted by moving the switch at the bottom from the center toward "slower". This will seem to enlarge the clip strip within the bottom meter, but it still plays slowly. For larger-sized playback, (full screen) click the play button to the right of normal play button (it's a white triangle within a dark rectangle background).

**Note:** All actions can usually be corrected by the 'undo' feature under "Edit" on the menu bar.

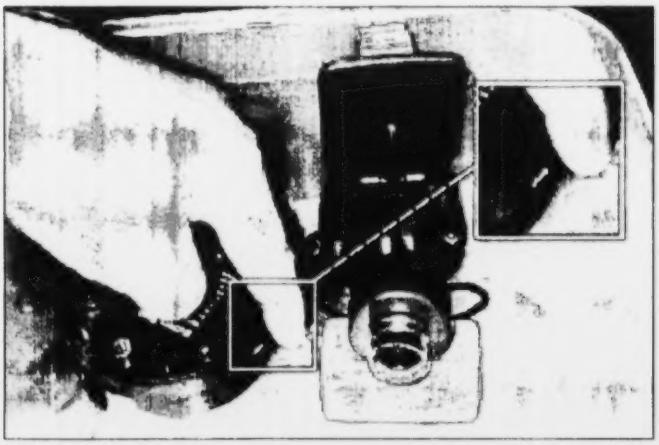
Although this brief describes the use of Imovie video editing software for MacIntosh computers, there are comparable PC video editing software available. For example, Microsoft XP Professional features software that is almost identical to Imovie's console and operation.

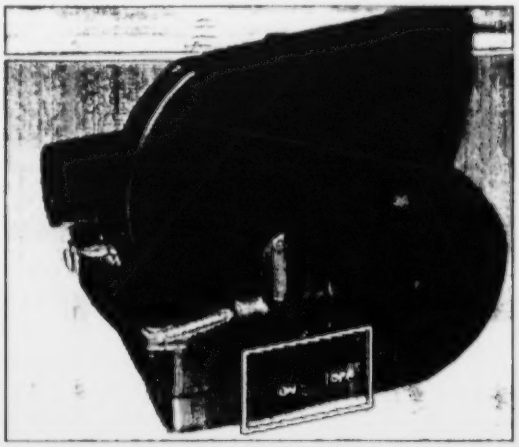
### Technical problems

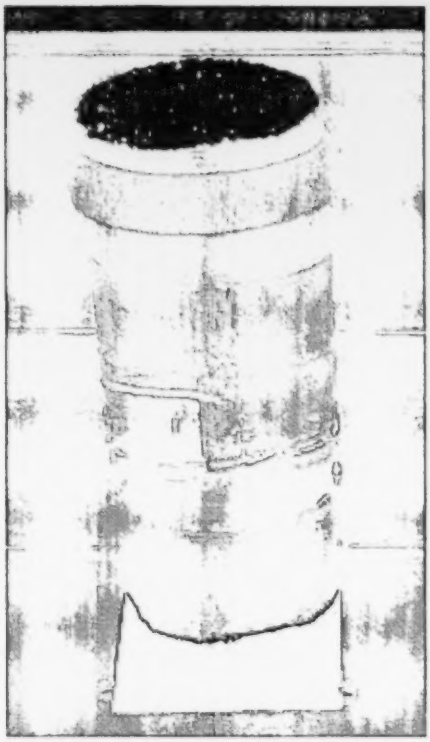
Due to excessive camera movement, a synchronization problem sometimes occurs. This problem appears on the video display on the laptop as a horizontal bar across the bottom or top of the screen (much like a glitch in V-hold). To correct this, stop recording or video display by hitting import or the play button. Then hit play or import again, and the camera will re-sync itself.

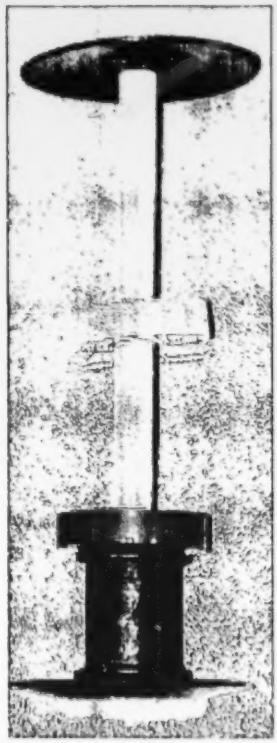
### Helpful reminders for setting up demonstration

Be sure all switches are in the "on" positions and refer to the following illustrations for securing payloads. The magnet stand fastens the same way the flat timer does.

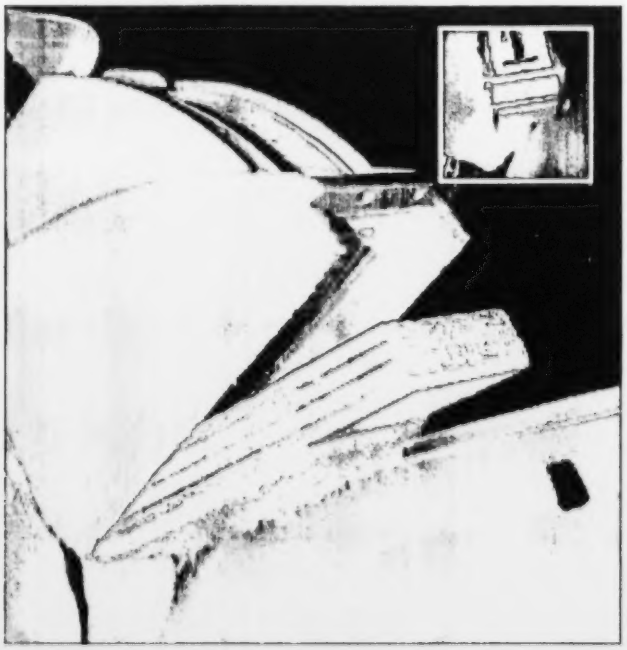


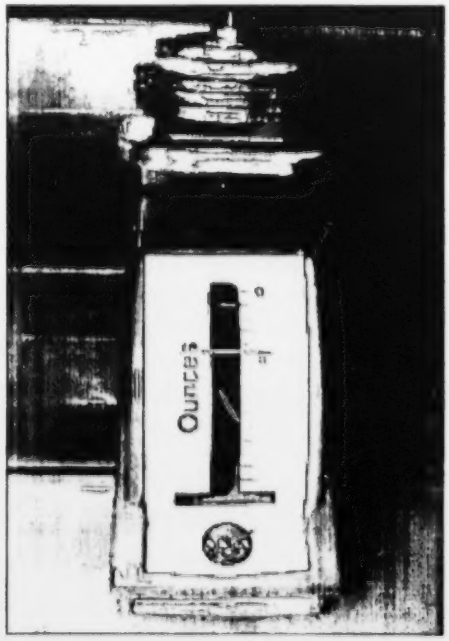






**Note:** The scale will need a spacer made of four pieces of 1/8" thick balsa wood glued together with a strip of loop-type Velcro™ across the bottom to fasten to the drop box.



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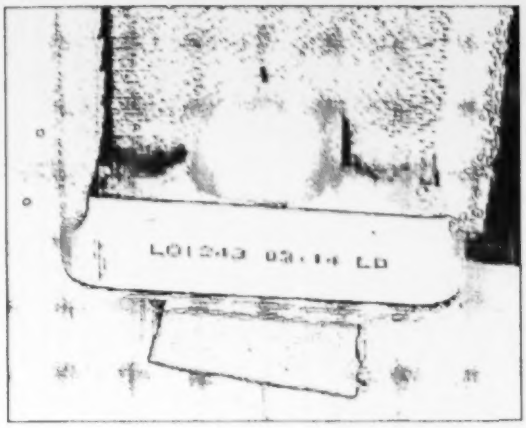
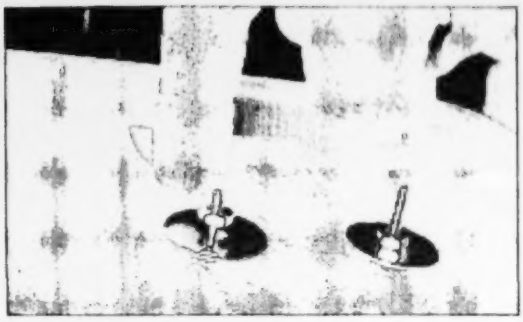
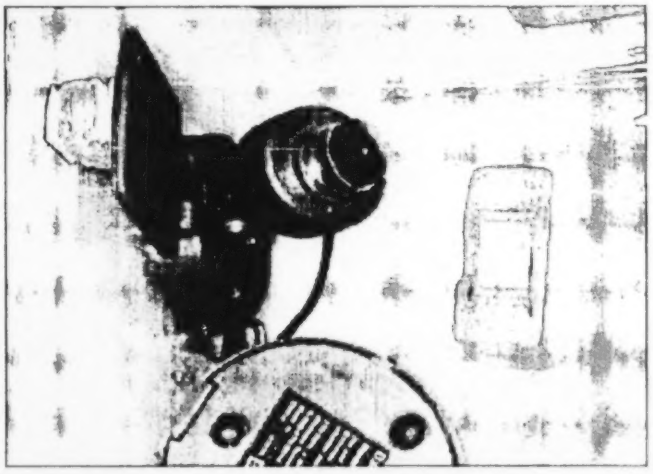
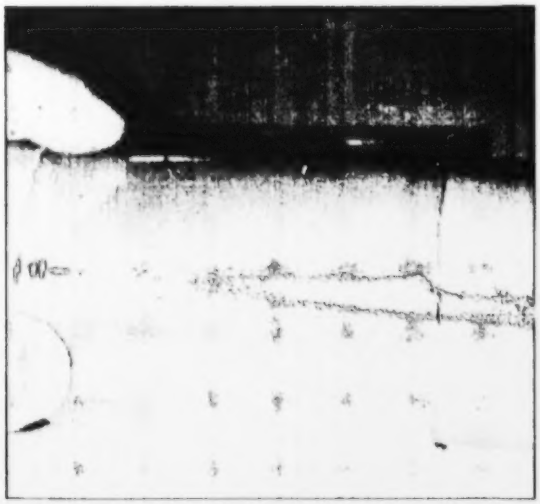
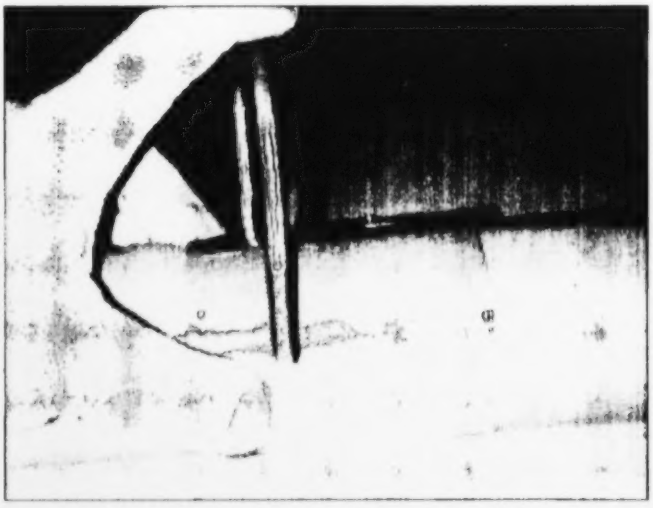






Placing a chin rest beneath the camera will help reduce whiplash on impact. Stack and glue balsa strips to form a saddle for the camera to sit in. For extra care use a strip of electrical tape or duct tape to strap camera head to chin rest.





Be sure to position the plastic sleeve on the top pipe prior to attaching the exhaust clamps and latch. This will help the U-bolts to slide on as well as allow the latch and release line return to resting or locked position.

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